Estimating Aerobic Power without Exercise Testing

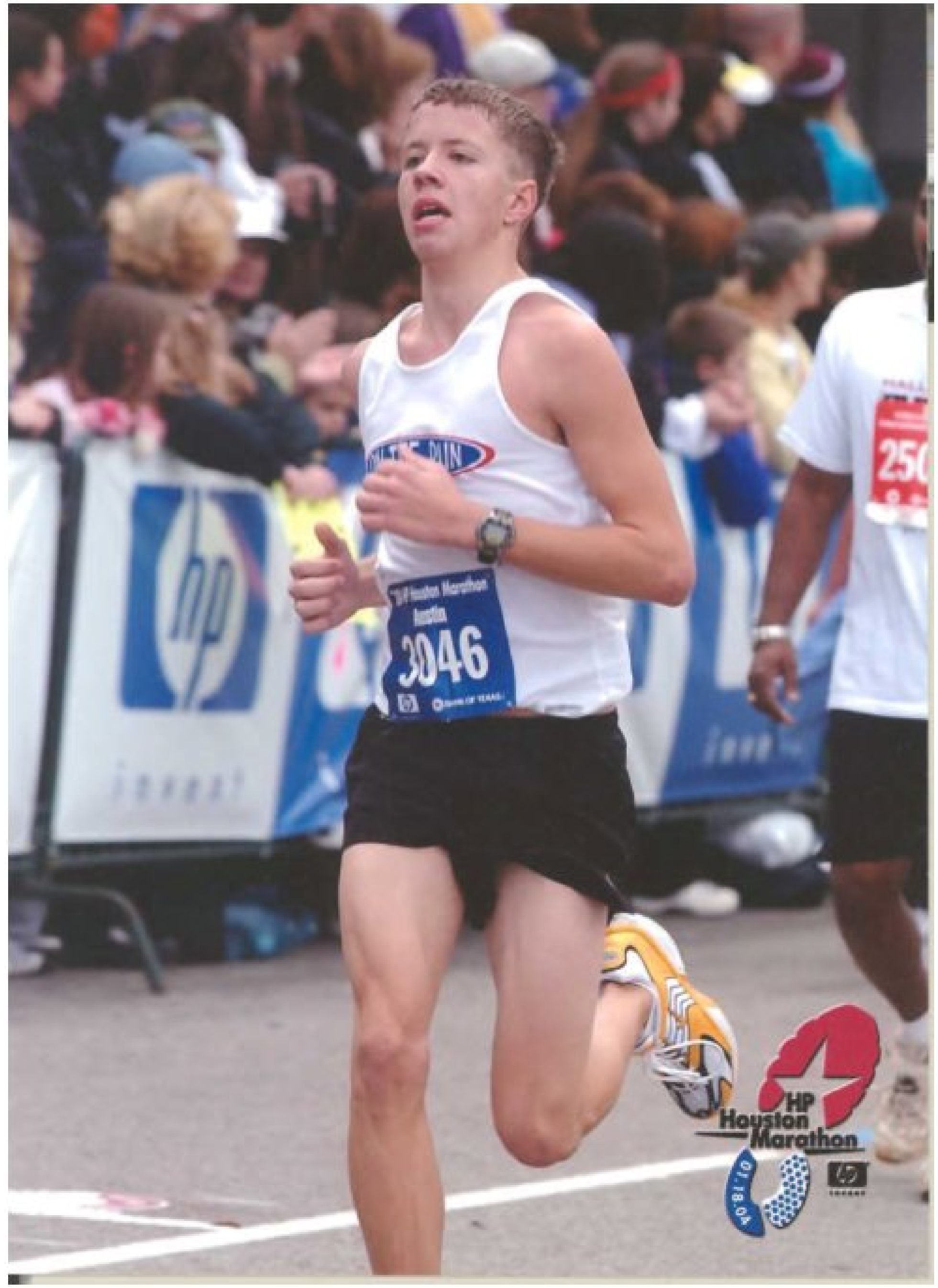
Larry T. Wier, Ed.D.
Exercise Scientist
NASA/Johnson Space Center

Background

- What is aerobic power?
- Why should we care about it?

Aerobic Power

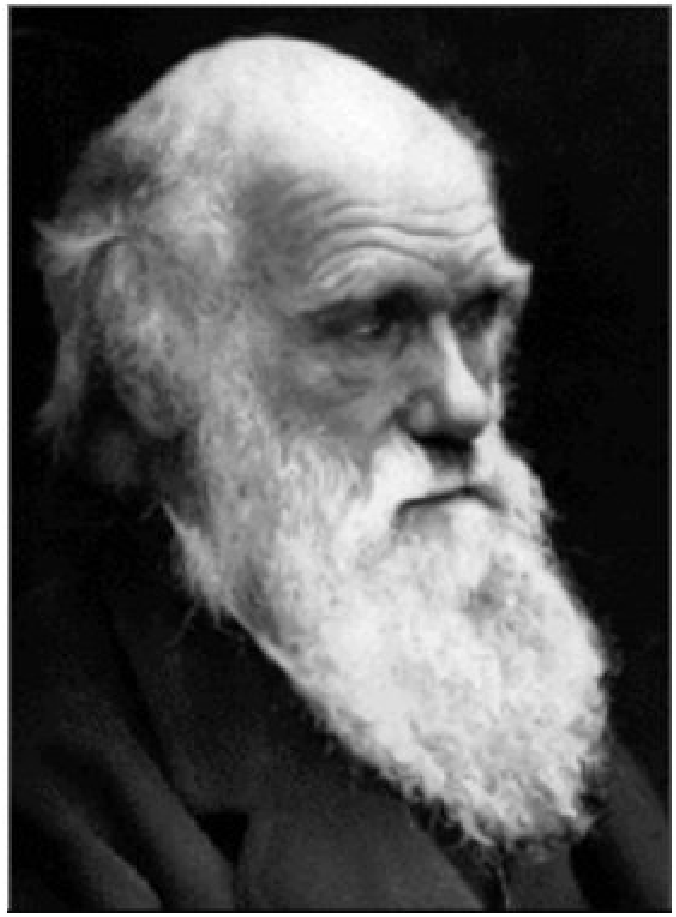
- VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)
- Dependent on the ability of the heart, lungs, blood vessels and blood to furnish oxygen to the muscles and on the capacity of the muscles to process oxygen for long-term effort
- Best single index of physical work capacity
- Key component in health-related fitness



Health-Related Components of Physical Fitness

- **Aerobic Power (VO_2max)**
- **Body Composition (% Fat)**
- Muscle Strength and Endurance
- Flexibility

“Survival of the Fit*NESS*”--1859



Coronary Heart Disease in Transport Workers

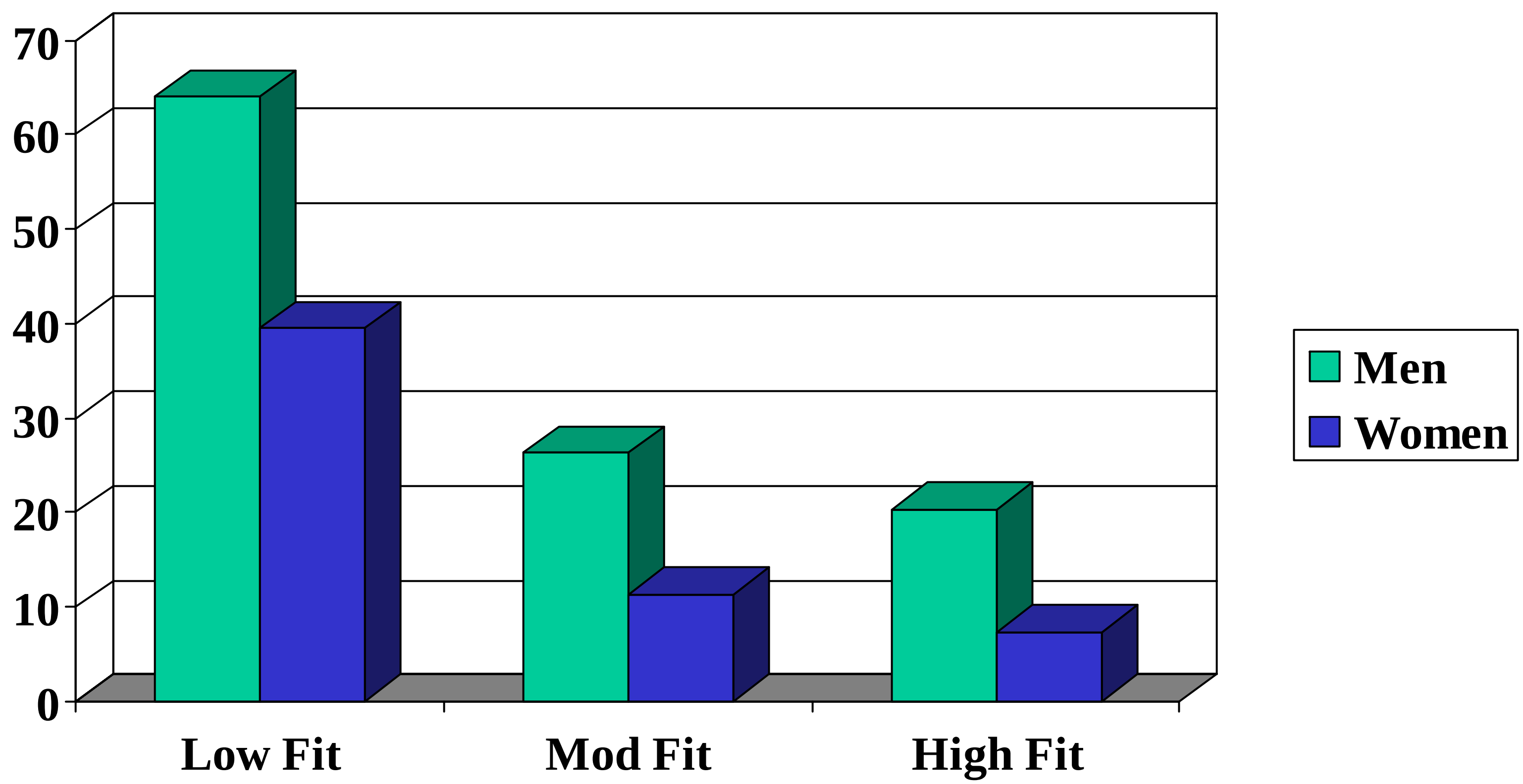
Morris, J.N. and P. Raffle. *British Journal of Industrial Medicine*. 1954. 11:260-72

- Conductors (active) had 30% lower incidence of CAD than drivers (inactive).
- Conductors had half the CAD mortality rate of drivers.

The Influence of Physical Fitness on Death Rates from All Causes

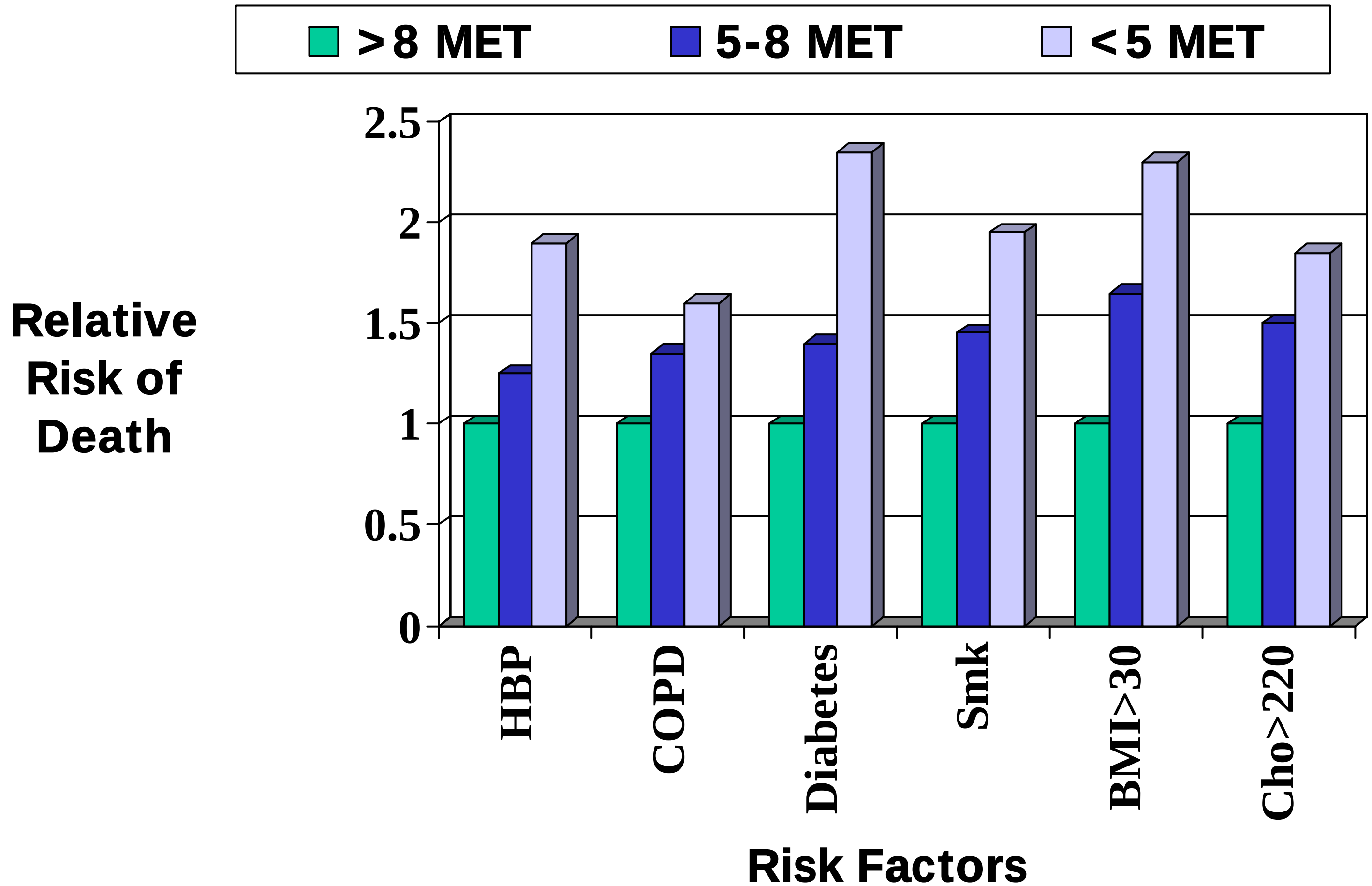
Per 10,000 person-years

(Blair, S. H. Kohl, R. Paffenbarger, D. Clark, K. Cooper, L. Gibbons. Physical fitness and all-cause mortality, *JAMA*, 1989,262:2395-2401)

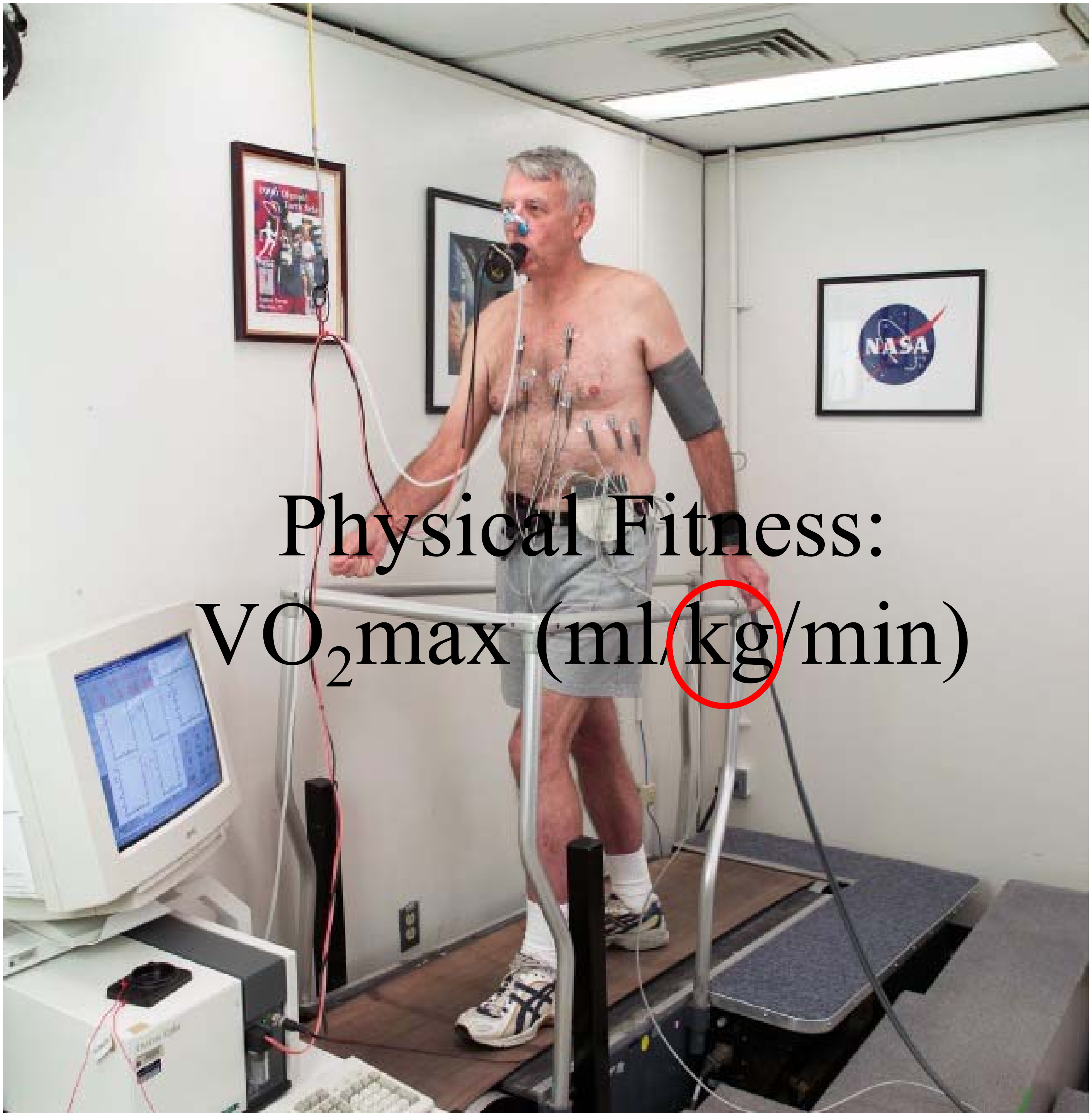


Exercise Capacity and Mortality

(Myers,J., M. Prakash, V. Froelicher, D. Do, S. Partington, J. Atwood. Exercise capacity and mortality among men referred for exercise testing. *New England Journal of Medicine* 2002, 346:793-801)



Physical Fitness: VO_2max (ml/kg/min)



What are the determinates of aerobic power?

- Heredity
- Gender
- Age
- Training/Activity Habit
- Body Fatness/Leanness

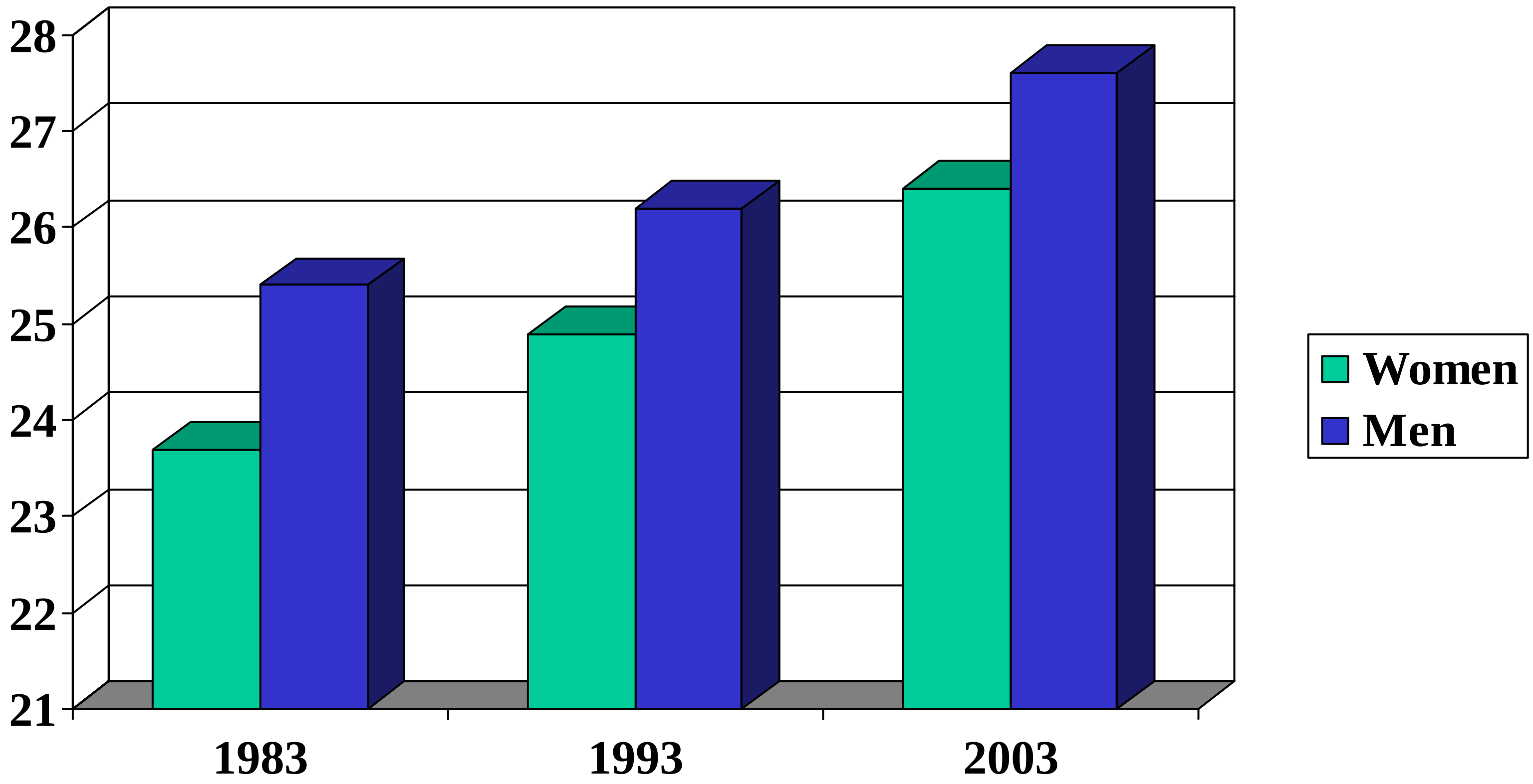
Aging, Fat, Activity and Aerobic Power

Jackson, A., E. Beard, L. Wier, R. Ross, J. Stuteville, S. Blair. Changes in aerobic power of men ages 25-70 years. *Med Sci Sports Exerc*. 1995, 27:113-120.

Jackson, A., L. Wier, G. Ayers, E. Beard, J. Stutteville, S. Blair. Changes in aerobic power of women, ages 20-64 years. *Med Sci Sports Exerc*. 1996, 28:884-91.

	Simple	Linear	Multiple	Regression
Variable	Men	Women	Men	Women
Intercept	59.48	50.30	47.78	45.59
Age	-0.46	-0.49	-0.26	-0.27
%Fat			-0.22	-0.31
Activity			3.27	2.184
%Fat X Activity			-0.08	-0.04
R	0.45	0.63	0.79	0.85

20-Year Comparative Mean BMI for JSC Employees



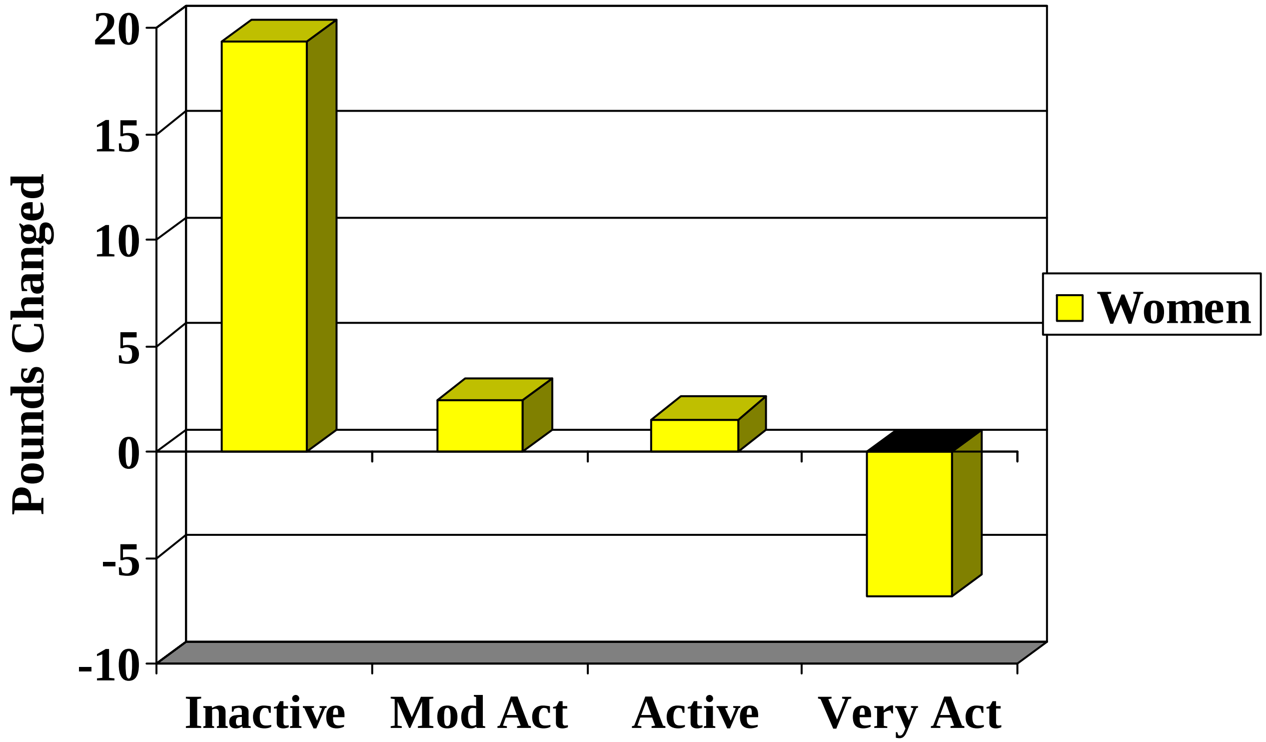
Ten-Year Changes in Body Weight and Blood Lipids in NASA/JSC Employees

(Wier, L., A. Jackson, G. Ayers, Longitudinal assessment of 10-year weight change in a large federal workforce. *Med Sci Sports Exerc* 1996; 28: (supplement): S43, 252)

	Men	Women
Weight (lb)	8.58*	15.66**
Chol (mg/dl)	11.59*	21.73**
LDL Chol (mg/dl)	11.08*	10.79**
HDL Chol (mg/dl)	-3.18*	-2.00**
Trigs (mg/dl)	23.06*	41.82**
	*P<0.001	**P<0.01

Long Term Changes in Body Weight by Activity Level

(Wier L., G. Ayers, A. Jackson, A. Rossum, W. Poston, J. Foreyt. Determining the amount of physical activity needed for long-term weight control; *International Journal of Obesity*; 2001; 25:613-621)



Diseases and Disorders Related to Poor Fitness and Obesity

- **Poor Physical Fitness**
  - **Heart Disease**
  - **Cancer**
  - **Stroke**
  - **Diabetes**
  - **Hypertension**
  - **Abnormal Blood Lipids**
  - **Osteoporosis**
  - **Chronic Backache**
  - **Obesity**
- **Obesity**
  - **Heart Disease**
  - **Cancer**
  - **Stroke**
  - **Diabetes**
  - **C.O.P.D.**
  - **Hypertension**
  - **Abnormal Blood Lipids**
  - **Gallbladder Disease**
  - **Osteoarthritis**

Tests to Determine VO_2max

- Measured by Indirect Calorimetry at maximal exertion ("gold standard")
- Estimated by –
  - Maximal tests on a Treadmill, 1.5 to 2-mile run
  - Sub-maximal tests on a treadmill, stationary bike, bench step, 1-mile walk
  - Non-exercise models

Prediction of Functional Aerobic Capacity Without Exercise Testing

Jackson AS, Blair SN, Mahar MT, Wier LT, Ross RM, Stuteville JE, *Medicine and Science in Sports and Exercise*, 1990; 22:863-870

Regression coefficients for calculating VO_2max (ml/kg/min)

Variable	% Fat Model	BMI Model
Constant	50.513*	56.363*
Age	-0.289*	-0.387*
Gender	5.863*	10.987*
Activity	1.589*	1.921*
%Fat/BMI	-0.552*	-0.754*
R	0.812*	0.783*
SEE (ml/kg/min)	5.35	5.70

*P<0.001

NASA ACTIVITY SCALE

Select the number which best describes your total weekly activity level for the previous month.

Sedentary to light exercise:

0—avoid walking or exertion, always use the elevator, etc.

1—walk for pleasure, occasionally sweat with exercise

Modest exercise, like yard work, golf, bowling, etc.

2—10-60 minutes/wk

3—over an hour/wk

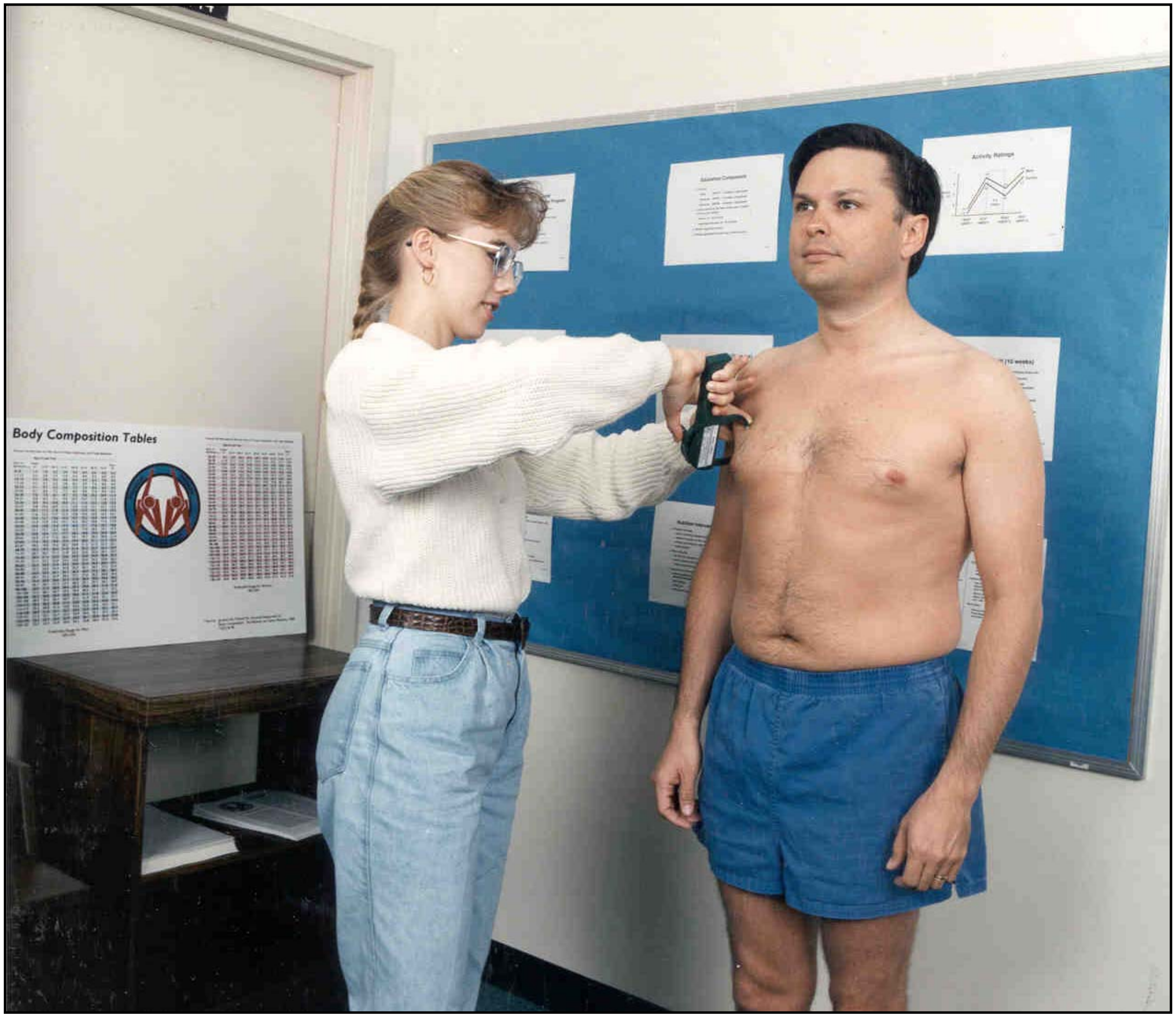
Heavy aerobic exercise like running/brisk walking or comparable activity like tennis, basketball, etc.

4—Run ~1 mi/wk, walk 1.5 mi/wk or ~30 min/wk comparable

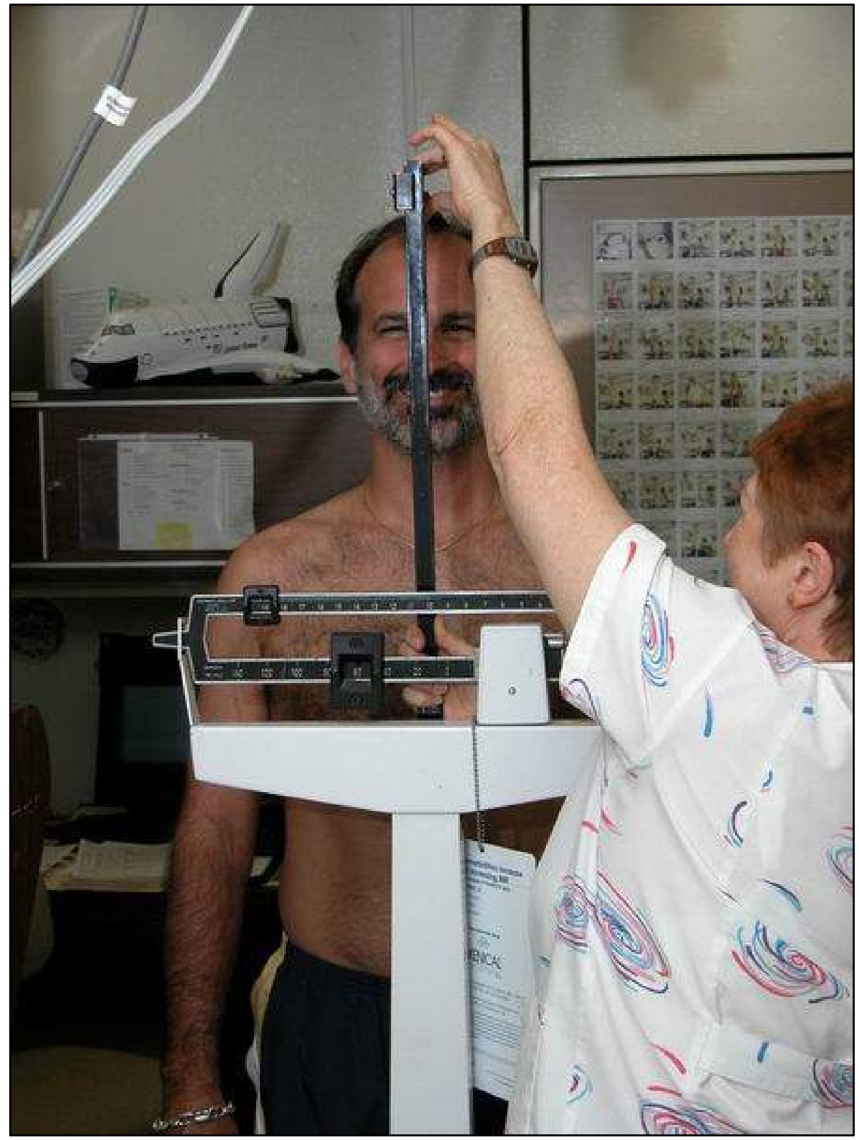
6—Run 6-10 mi/wk, walk 7-14 mi/wk or 1-3 hrs/wk comparable

10—Run >25 mi/wk, walk >34 mi/wk or >12 hrs/wk comparable

Percent Fat by Skin-folds



Body Mass Index = Weight in Kg/(Height in meters)^2



Waist Girth Measurements Starting in 1993

Waist Girth, Physical Activity, Fitness and Selected Disease Risks in JSC Employees

(Values are means; all differences are significant at $P<0.01$)

		Women N=448			Men N=2478	
Waist	<28	28-34.9	$\geq$35	<33	33-39.9	$\geq$40
%Fat	22.5	29.3	35.0	14.9	21.3	28.3
Activity	5.1	4.1	2.9	5.7	4.9	3.7
VO_{2max}	34.7	29.1	24.3	42.8	36.3	28.2
Chol	192.0	206.3	218.7	189.3	205.0	225
Smoke-Pack/yr	1.4	2.1	3.5	1.5	3.3	7.4

Nonexercise Models for Estimating VO_2max with Waist Girth, Percent Fat, or BMI

Larry T. Wier, Andrew S. Jackson, Greta W. Ayers, and Brian Arenare

Kelsey-Seybold Clinic, NASA/Johnson Space Center, Houston, Texas; and University of Houston, Houston, Texas

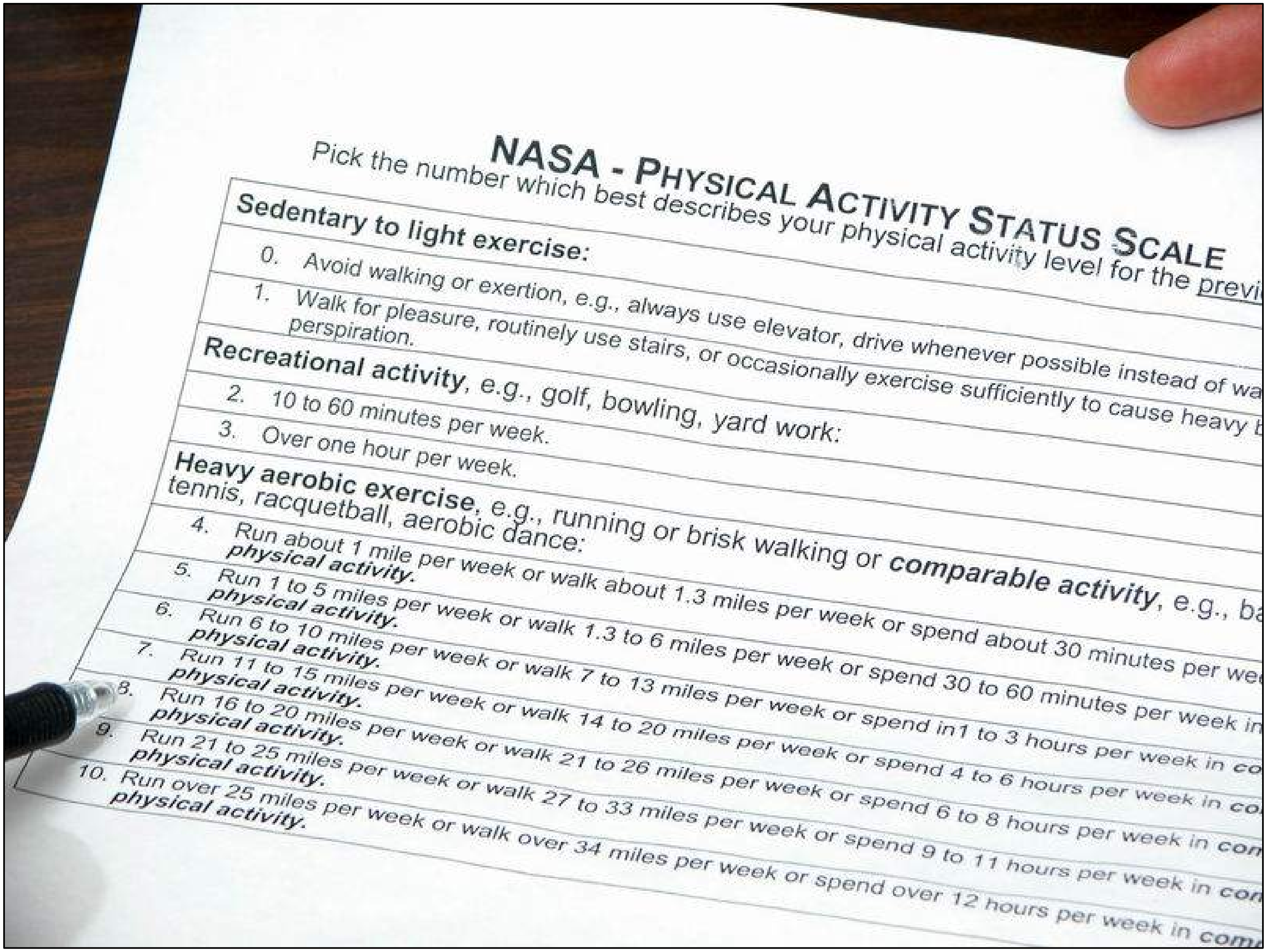
Purpose of Study:

- To investigate the use of waist girth as a surrogate for body composition in the nonexercise models
- Compare the accuracy in estimating VO_2max for the nonexercise models that included waist girth, %fat, or BMI


NASA

2417 Men

Selecting an Activity Rating



NASA - PHYSICAL ACTIVITY STATUS SCALE

Pick the number which best describes your physical activity level for the previ

Sedentary to light exercise:

0. Avoid walking or exertion, e.g., always use elevator, drive whenever possible instead of wa
1. Walk for pleasure, routinely use stairs, or occasionally exercise sufficiently to cause heavy b perspiration.

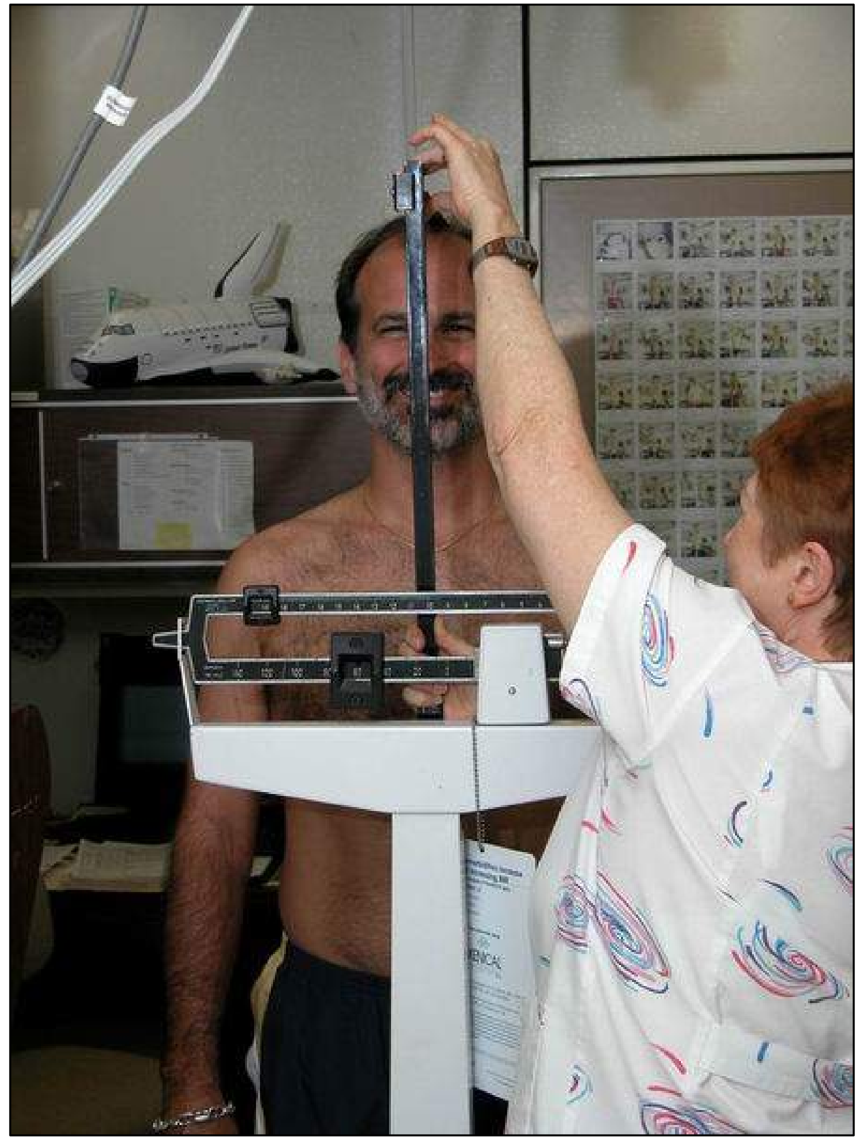
Recreational activity, e.g., golf, bowling, yard work:

2. 10 to 60 minutes per week.
3. Over one hour per week.

Heavy aerobic exercise, e.g., running or brisk walking or **comparable activity**, e.g., ba tennis, racquetball, aerobic dance:

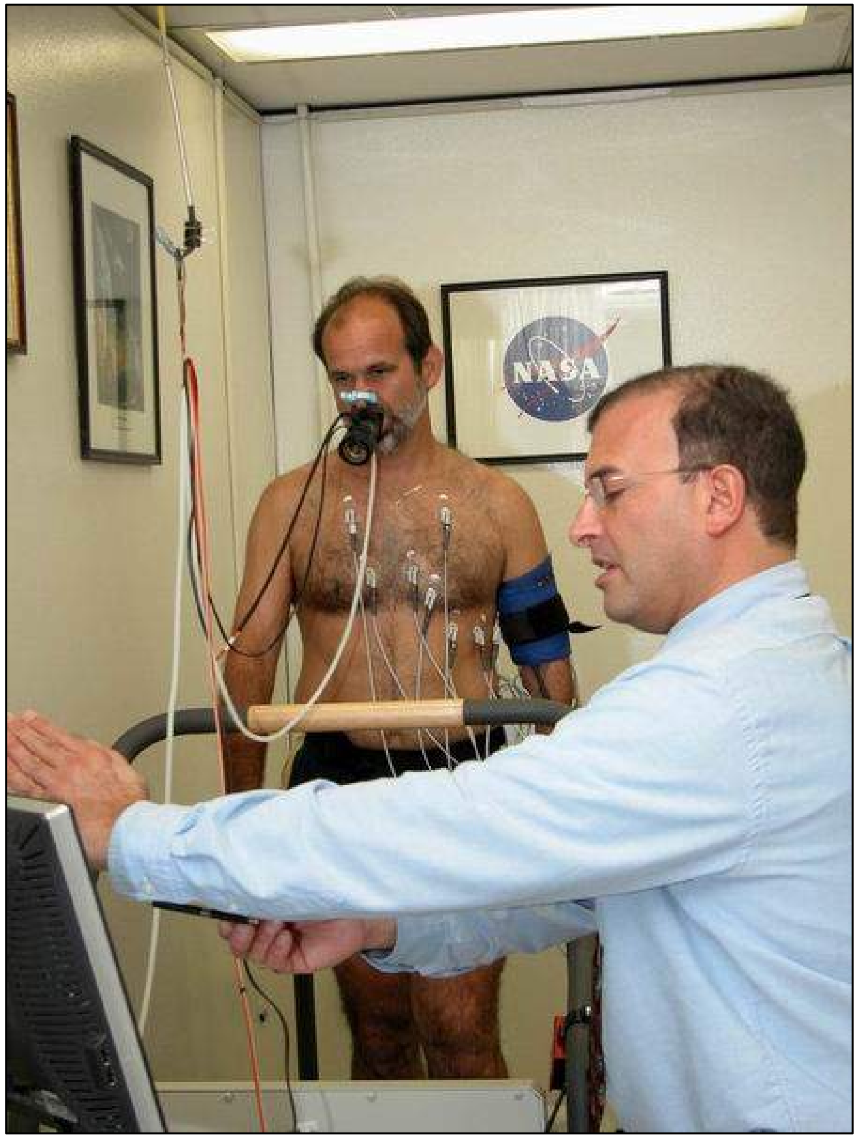
4. Run about 1 mile per week or walk about 1.3 miles per week or spend about 30 minutes per we ***physical activity.***
5. Run 1 to 5 miles per week or walk 1.3 to 6 miles per week or spend 30 to 60 minutes per week in ***physical activity.***
6. Run 6 to 10 miles per week or walk 7 to 13 miles per week or spend in1 to 3 hours per week in co ***physical activity.***
7. Run 11 to 15 miles per week or walk 14 to 20 miles per week or spend 4 to 6 hours per week in co ***physical activity.***
8. Run 16 to 20 miles per week or walk 21 to 26 miles per week or spend 6 to 8 hours per week in com ***physical activity.***
9. Run 21 to 25 miles per week or walk 27 to 33 miles per week or spend 9 to 11 hours per week in com ***physical activity.***
10. Run over 25 miles per week or walk over 34 miles per week or spend over 12 hours per week in com ***physical activity.***

Measurement of Body Weight and Height



Percent Fat by Skin-folds and Measurement of Waist Girth

VO_2max by Indirect Calorimetry



Descriptive Statistics (N=2801)

	Men (2417)			Women (384)		
	Mean	SD	Range	Mean	SD	Range
Age	50.0	10.7	21-82	42.4	9.0	19-67
Ht (cm)	177.2	6.4	150-200	163.7	6.1	145-182
Wt (kg)	82.4	12.1	49-168	64.2	11.6	42-114
BMI	26.2	3.4	17.7-48.6	24.0	4.2	16.0-41.8
% Fat	21.1	6.0	4.3-38.0	26.4	7.0	11.1-42.6
WG	92.2	10.2	61.0-158.0	74.3	10.5	59.0-125.0
Activity	5.0	2.1	0-10	4.6	2.3	0-10
VO2max	36.4	8.1	15.4-65.5	31.9	7.5	17.0-59.1
RER	1.2	0.1	1.1-1.8	1.2	0.1	1.1-1.5

Zero-Order Correlations Between Measured VO_2max and the Independent Variables

	Correlation	P
Gender (M=1, F=0)	0.191	0.000
Age (years)	-0.532	0.000
Activity (0-10)	0.541	0.000
% Body Fat	-0.654	0.000
BMI	-0.392	0.000
Waist Girth (cm)	-0.392	0.000
Treadmill Time (min.)	0.903	0.000

Multiple Regression Models Estimating VO_2max

	Waist Girth	% Fat	BMI
Constant	59.416*	51.936*	57.402*
Age (years)	-0.327*	-0.308*	-0.372*
Gender (M=1, F=0)	11.488*	4.065*	8.596*
Activity (0-10)	1.297*	1.217*	1.396*
Waist/%Fat/BMI	-0.266*	-0.483*	-0.683*
R	0.810*	0.817*	0.802*
SEE (ml/kg/min)	4.799	4.716	4.900
SEE%	13.393	13.161	13.675

*P<0.001

Prediction Accuracy for Subgroups

- Constant Error (CE) = $\sum$(Measured VO_2max – Predicted VO_2max)/n
- Gender CE's were <0.05 ml/kg/min and essentially equal for Males and Females
- For subgroups of Age and Activity
  - Models were most accurate for older (> 50 yr), less active (Activity < 6.5) individuals
  - For younger Age groups CE < 0.20 ml/kg/min
  - For high Activity group CE < 0.90 ml/kg/min
- For subgroups of VO_2max
  - CE < 0.60 ml/kg/min for VO_2max between 30 and 50 ml/kg/min
  - CE > 3.0 ml/kg/min for VO_2max < 30 and > 50 ml/kg/min

Constant Errors (CE) of Models by VO_2max Subgroups

(Values are CE & SD)

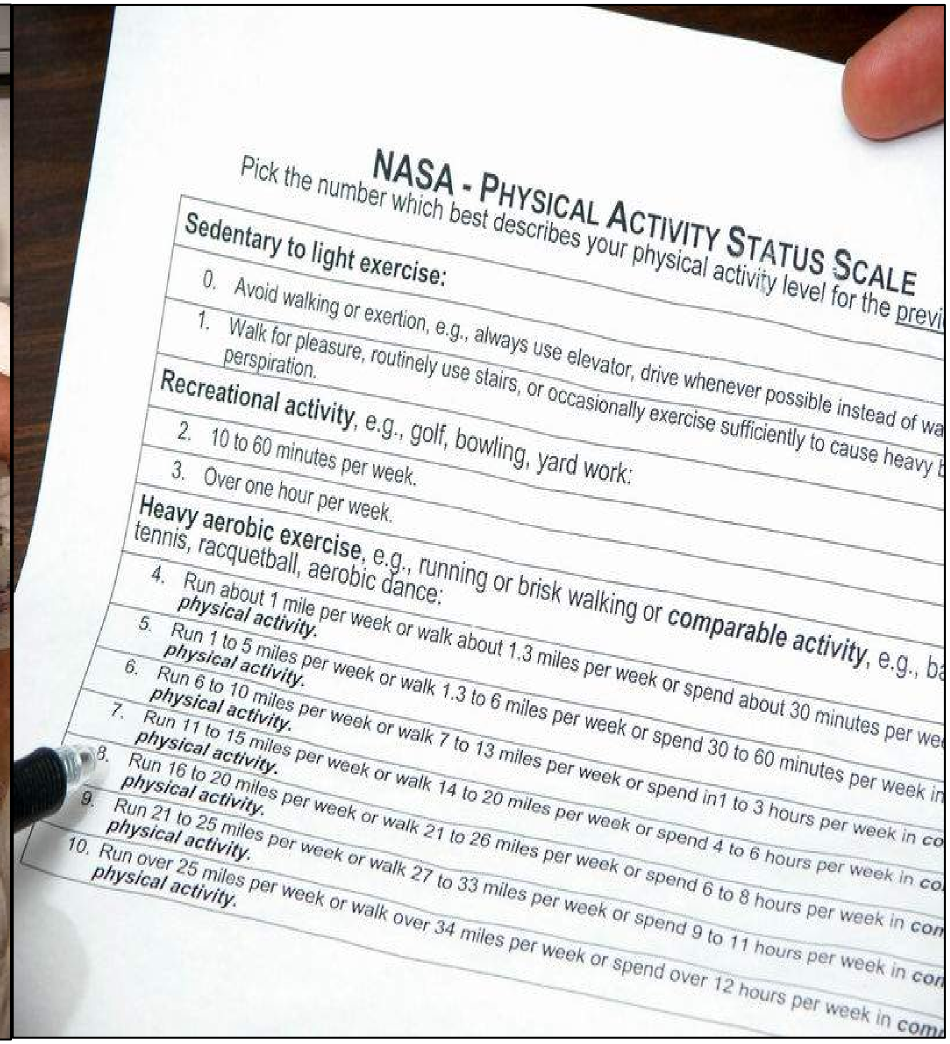
VO_2max (ml/kg/min.)	N (%)	Waist Model Residuals	% Fat Model Residuals	BMI Model Residuals
<30	664 (24%)	-2.98 4.29	-3.08 4.24	-3.04 4.42
30 – 50	1936 (70%)	0.39 4.21	0.53 4.12	0.44 4.25
>50	152 (6%)	7.41 3.86	6.90 3.94	7.84 3.73

Conclusion:

- The model with waist girth predicts VO_2max with equal or better accuracy than models using either % fat or BMI. Therefore, waist girth is an appropriate surrogate for body composition in the non-exercise model.
- Compared to sub-maximal exercise models, the nonexercise models estimate VO_2max with equal or superior accuracy and they tend to be safer, less expensive, quicker and more convenient
- All models provide valid estimates of VO_2max for most adults, but with reduced accuracy at the extremes of fitness

Max Treadmill Time Method
(R=0.91; SEE=3.4 ml/kg/min.)

Waist Girth Method
(R=0.81; SEE=4.80 ml/kg/min.)



Applications

- Fitness Professionals
  - Perform quick and accurate fitness assessments
  - Use assessments to design physiologically appropriate exercise prescriptions (beyond exercise heart rate)
- Medical/Healthcare Professionals
  - Estimate VO_2max in the office
  - Use VO_2max cut-offs to identify high-risk patients

Estimating VO_2max and prescribing workloads from sample data

Sample Data

Sex	Age	Act	WG	BMI	%Fat
Male	50	4	92.7	26.6	21.5

Estimated VO_2max (ml/kg/min)

WG Model - 35.1 BMI Model - 35.3 %Fat Model - 35.0

Workloads at 70% of VO_2max

TM (flat)	TM (4%)	Bike Erg	EFX	Rower
4.5 mph	4.0 mph	150 watts	7 Mets	573 kcal/hr

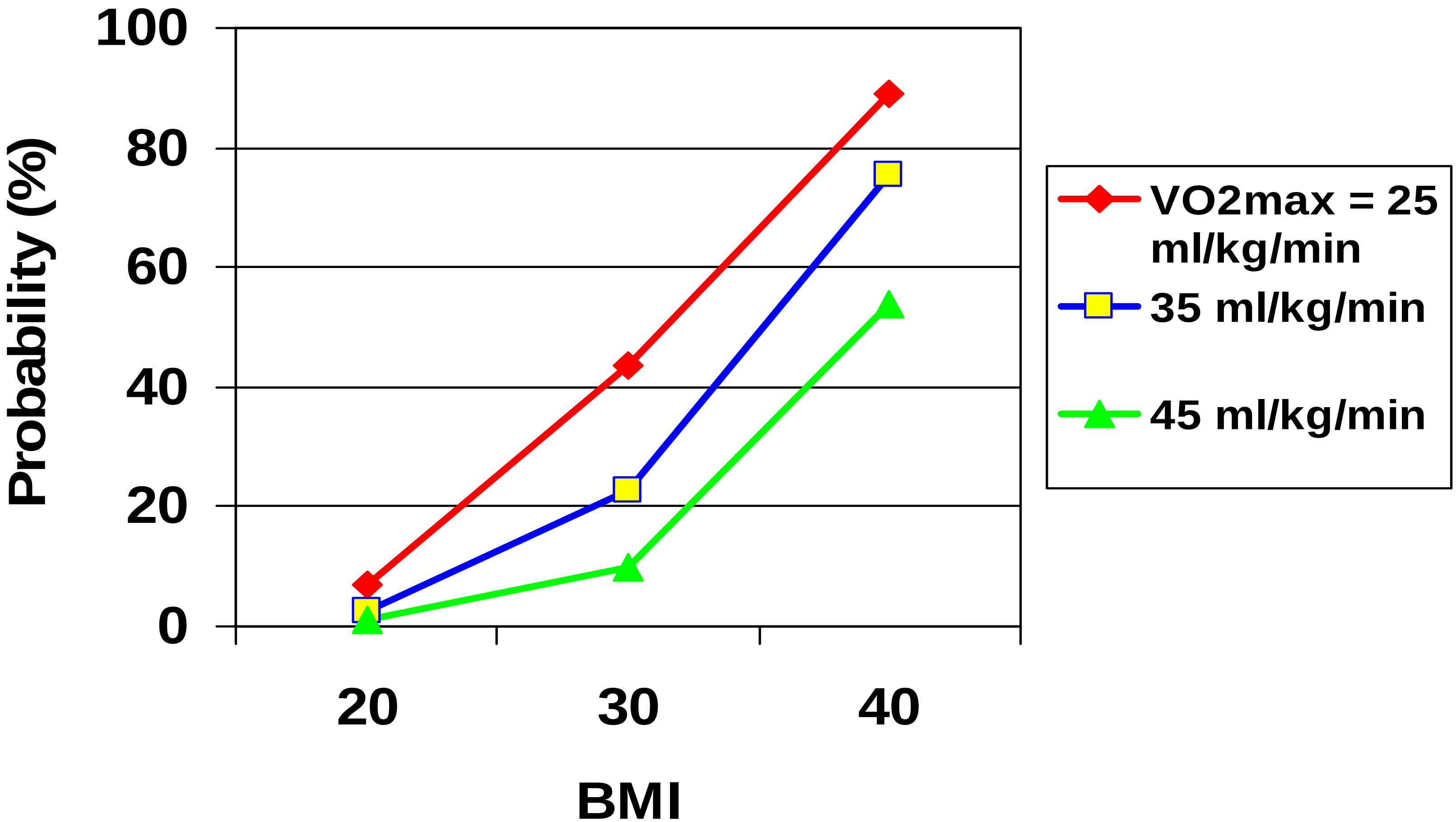
Low VO_2max (ml/kg/min) – ACLS* and the non-exercise (NX**) value

Age	<40		40-49		50-59		>60	
Men	ACLS <37	NX <42	ACLS <35	NX <38	ACLS <31	NX <33	ACLS <26	NX <29
Women	ACLS <34	NX <39	ACLS <32	NX <35	ACLS <28	NX <30	ACLS <24	NX <27

*ACLS: Aerobics Center Longitudinal Study values for low fitness
**NX: Non-exercise estimate adjusted by the Receiver Operator Curve technique

Physical Fitness Risk Profile for Metabolic Syndrome (Men)

(Wier, LT, AS Jackson, GW Ayers, N Urban, B Arenare. Physical fitness risk profiles for metabolic syndrome. *Med. Sci. Sports Exerc*. 2006 (in press))



Summary

- The high value of physical fitness in health is explained by the relationship with VO_2max.
- Habitual physical activity produces improvements in both VO_2max and body composition and these two factors interactively affect health.
- VO_2max can be accurately estimated by age, gender, activity habit and differing expressions of body composition (WG, %Fat, or BMI)
- These nonexercise models have application for health and fitness professionals.